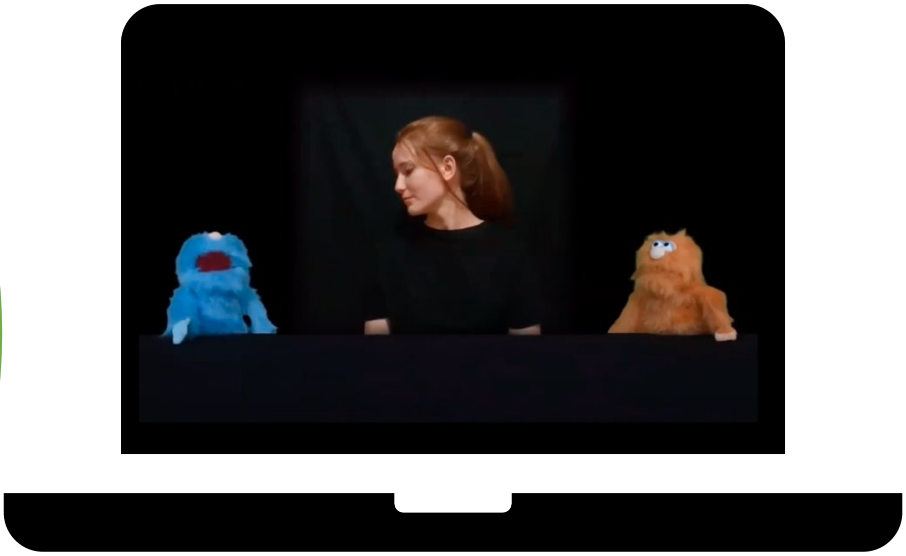
newsletter

Harvard Lab for Developmental Studies



2022

Contents

Fingers as Tallies

Peggy Li (Research Fellow); Sarah Chiang, Crystal Gill, Tyler Neri, Peggy Yin (Undergraduate Research Assistants); Susan Carey (Principal Investigator)

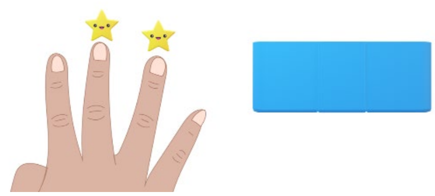
Numbers are so essential to contemporary human activity—data processing, scheduling, trading—that it seems only natural that natural numbers (1, 2, 3, …) are, well, *natural*. But such number concepts may not be innate to humans after all: in cultures without counting systems (“one, two, three, …”), even adults tend to make errors when asked to match sets greater than 4 or to perform arithmetic. Also surprisingly, while most 2-year-old American children can recite numbers 1 through 10, they do not understand the logic of counting. For example, children may count a set correctly but fail to understand that the last word they reach when counting indicates how many items are in the set.

This project explores representations that may have supported the cultural invention of counting systems by testing 3- and 4-year-olds. Specifically, we focus on tallying, which served as a precursor to counting as a way for ancient human cultures to represent exact numbers. These tally systems often made use of fingers as tallies, where one finger represented exactly one object. We asked whether children could use fingers to represent an exact number of objects, even before learning how to count.

In one study, we explained to children that fingers in one-to-one correspondence with objects could help us represent how many there are (“We raise one finger for one donut. The fingers raised can show how many donuts there are.”). Children were shown fingers raised and lowered as objects were added to or subtracted from a set. Then, to see whether children understood our explanation, we asked them to use their fingers to show how many objects when objects were added or subtracted from sets, and to show how many there were in pictures. We found that the idea of using finger tallies to represent sets may not initially be intuitive: many children, instead of raising or lowering the number of fingers appropriately, simply pointed to each object with their index finger. However, some children who had not worked out the logic of counting, did appreciate our instructions and tried to match the number of fingers they held up to the number of items presented.

Another study sought to find whether children could use finger tallies to track objects. For this study, children were provided finger tallies in one-to-one correspondence with stars entering and exiting a box. If children intuitively understand how tallies can represent exact large numbers, then we should expect to see improvement on this task compared to results from the same task without finger tallies, regardless of children's counting knowledge. We then asked the children whether all of the objects had come back or whether some remained in the box. We found that even children who did not know how to count could improve their performance on the task when provided with finger tallies.

Overall, these studies begin to shed light on children's developmental understanding of tallying and the role tallying could play in the cultural invention of counting systems



Can older siblings teach younger siblings new words?

Joseph Coffey (Graduate Student); Jesse Snedeker (Principal Investigator)

Throughout the world, children play an important role in the care and instruction of their younger siblings. In many societies, children spend more time in conversation with their peers than they do with their adult caregivers. Even in societies where children have fewer siblings and spend less time with them on average, older siblings have been found to proactively teach language and literacy concepts to their younger charges. These findings suggest that having older siblings can positively impact children's early language development.

Surprisingly, the literature on language development has little to say about the effects of older siblings. Almost no studies of word learning have recorded children's conversations with their siblings. Of those that have, few have found sibling speech to predict children's vocabulary growth. One possibility for this is that older siblings are not as proficient teachers as parents are. Children may be unable to learn as effectively from older siblings' speech, which tends to be less pedagogical than parents' speech. They may also not believe older siblings are reliable sources of information and prefer to learn from adults.

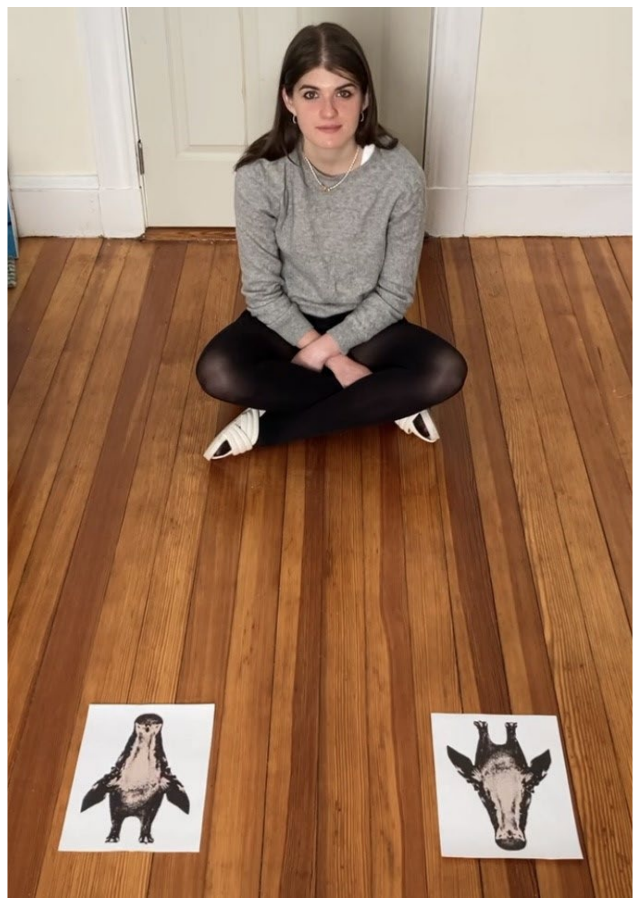
Our study tested these competing theories by examining whether children learn new words through naturalistic instruction by their older siblings. We recruited families with two school-aged children to take part in this study. During the session, both parents and older siblings were taught how to play a version of Bingo that required they learn the names of four monsters, each with a made-up name. Afterwards, parents and older siblings were asked to teach the younger siblings how to play the game, including the names of each of the monsters. Parents and siblings were given slightly different games with some unique monsters, which also allowed us to compare the effectiveness of parent and sibling teaching. All participants were then assessed on how well they were able to recall the names of the monsters.

In our initial pilot of 10 families, we found that younger siblings were able to remember the names of the monsters taught by their older siblings. We also found that they tended to remember words taught by parents better than words taught by siblings, although this may have been because parents were better at learning the words themselves compared to older siblings. We also found some suggestive evidence that words taught by both parents and siblings are easiest to learn, but given our small sample this finding is still inconclusive. We look forward to updating you all on our discoveries as we continue to run participants over the next year!

Can 3-year-olds be influenced into taking the perspective of another person?

Laura Lee (Undergraduate Research Assistant); Brandon Woo (Graduate Student); Elizabeth Spelke (Principal Investigator)

A large body of research has found that 3-year-olds are unable to take the visual perspective of another person. For example, if you were sat across the table from a 3-year-old and both looked at a picture of a turtle (which looked upright to the child and upside down to you) and you asked the child if you yourself see the turtle upright or upside down, they will tell you that you see the turtle the same way they see it: upright. However, newer research has theorized that the reason 3-year-olds don't take others' perspectives is because when they are presented with their own view (e.g. upright) and another's view (e.g. upside down), it is simply easier for 3-year-olds to answer from their own perspective. To address this issue, we have designed an experiment on zoom to test whether 3-year-olds can more easily take another's perspective if their own view is not presented and only the experimenter's perspective is expressed. Pilot results have shown that 3-year-olds are more able to take another person's perspective if their own perspective is not stated. Data collection for the main study will begin shortly, and we will be using upright and upside-down pictures as well as optical illusions, such as an image that looks like a giraffe from one view and a penguin from another.

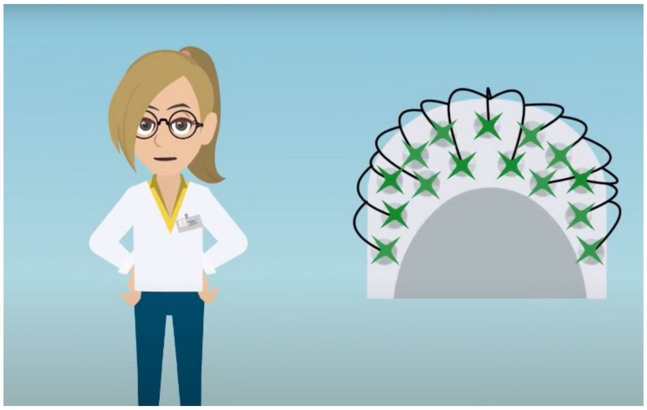


Solve a mystery! Do children predict the form of upcoming words?

Anthony Yacovone (Graduate Student); Briony Waite (Lab Manager); Jesse Snedeker (Principal Investigator)

In this study, we are investigating how children understand the words that they hear while listening to a story. As listeners, we must quickly turn incoming sounds into words and then use those words to build up meaningful sentences! Prior work has found that, instead of just passively listening to people speak, people also actively predict what someone is about to say! This process of predicting upcoming words seems to help us understand people better and allows us to notice when people make mistakes (e.g. saying *ceke* instead of *cake*). However, there are still open questions about linguistic prediction and how this ability develops!

So, to study this phenomenon, we asked your child to watch a 30-minute cartoon while we recorded their brain waves using electroencephalography (EEG). We looked at their brain's responses to various words spoken throughout the story. Some of these words were perfectly normal (e.g. *cake*) while others were slightly mispronounced (e.g. *ceke* or *vake*). More specifically, the story contained two types of mispronounced words: one type had the same initial sound (ceke instead of cake), and the other type rhymed with the original word (vake instead of cake).



If children are predicting certain words to come next in the story, then these mispronunciations should be quite surprising to hear, resulting in larger brain waves! The size of these brain waves often reflects how difficult it was to understand the error in the story—so, we are also interested in whether there are different sized responses to errors like *ceke* or *vake* when the original word was supposed to be *cake*. If the error is very similar to the expected word (e.g. *ceke* and *cake*), then the brain responses should be relatively small. We have evidence that this is true for adults, and the remaining question is if this is true in children!

We are so excited to be slowly resuming in-person studies, and we loved seeing families in our lab in-person! We are still collecting data for this study, so please stay tuned for updates in our newsletter next year.

Recognizing violations of physics over Zoom

Emily Walco (Graduate Student); Elizabeth Spelke (Principal Investigator)

Over the past several decades, researchers have demonstrated that infants are surprised by objects that behave in impossible ways. Even from just a few months of age, infants look longer when an object hovers in midair than when it remains supported, or when an object appears to roll through a wall than when it stops at one. Further research has shown that these types of surprising events seem to provide infants with special opportunities for learning; infants learn new things about surprising objects more easily than unsurprising ones, and they want to explore surprising objects more. In order to further explore the ways in which infants use surprise as a cue that there is something to learn, we had to first assess whether infants find physically impossible events surprising when they are displayed in pre-recorded videos over Zoom rather than live in the lab.

In this study, we showed 8-10.5-month-old infants videos of objects behaving in ways that were either surprising or unsurprising and recorded how long they looked to each event. Interestingly, we did not find evidence of infants tending to look longer to the surprising events. This could mean that the videos were not effective in evoking surprise, potentially because babies find it difficult to represent the 2-dimensional display as an accurate representation of the 3-dimension physical world, or that they do not have the same expectations of physics as they would in the real world. Future research should seek to replicate these findings with new videos to address this possibility.

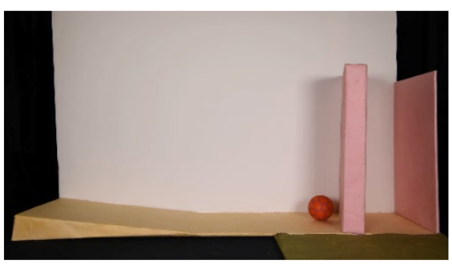


Figure 1 Ball appears to stop at wall

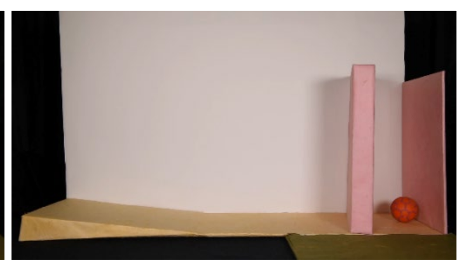


Figure 2 Ball appears to roll through wall

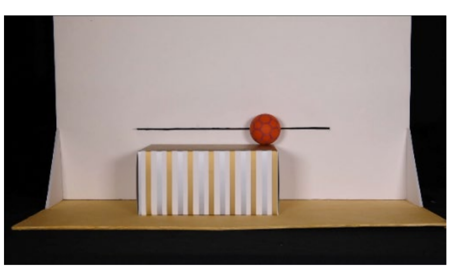


Figure 3 Ball remains supported

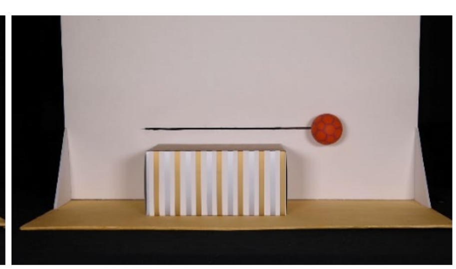


Figure 4 Ball appears to float in midair

Do infants learn more easily about an object that surprises someone?

Emily Walco (Graduate Student); Elizabeth Spelke (Principal Investigator)

When infants are born, there is so much information in the world around them that if they did not have some way of determining what to learn from and what to ignore, learning would be very overwhelming. Past research has shown that one way that babies can prioritize certain events to learn from is to pay special attention when something surprises them. Seeing something that doesn't match what the baby expects indicates to babies that there is something to learn. In past studies, infants learned new things about surprising objects more easily than unsurprising ones, and they tended to explore surprising objects more. One thing that we don't know yet is whether it's the *feeling* of surprise that triggers infants' learning about surprising objects, or if it's just the knowledge that something was surprising. One way to test this is to see whether infants can use someone else's surprise as a cue that there is something to learn. This would also allow for many more opportunities for babies to learn, such as when they weren't looking when something surprising happened, or when an event occurs that they might not know to find surprising.

In this study, we showed 18-month-old infants videos of an object rolling behind a wall with an adult watching from behind the wall. When one object rolls behind the wall, she smiles and says, "oh, cool!", but when a different object rolls behind she gasps and says, "oh, wow!". We then taught babies something a new word for the objects and then observed which object they looked at when we played the word again. If babies had learned about the surprising object more easily, they should look more to that object at test (compared to how much they looked at the unsurprising object when they were taught about that object). Preliminary results did not show a difference in looking depending on whether or not the adult had been surprised, but this study is still in early stages, so we don't have a clear answer to these questions just yet!

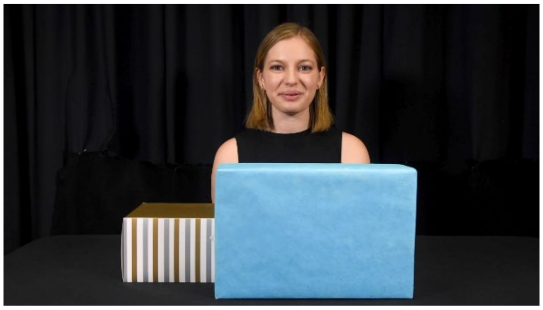


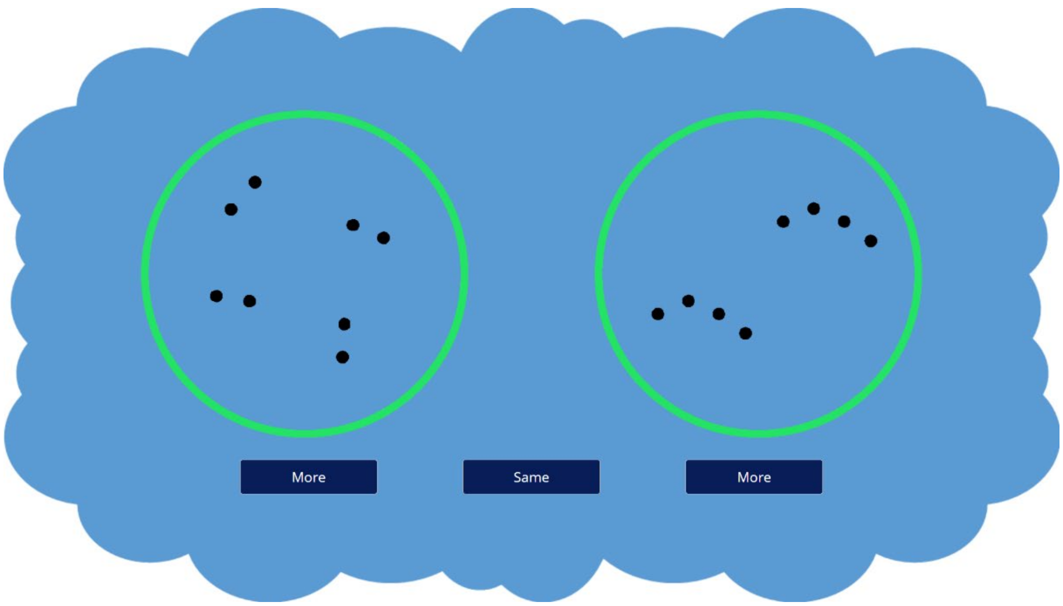
Figure 5 Experimenter is not surprised by the object

Figure 6 Experimenter is surprised by the object

Do elementary school children know that 2x4 = 4x2?

Marie Amalric (Postdoctoral Researcher); Elizabeth Spelke (Principal Investigator)

Mathematical symbols are culturally acquired knowledge, typically learnt over many years of schooling. While our symbolic abilities are often built upon our concrete understanding of quantities, formal learning of arithmetic operations also seems to reshape our perception of spatially organized dot arrays. In this study, we tested the influence of school learning about multiplication and its commutative principle on the perception of grouped dot arrays in 2nd and 3rd graders. In a More/Same/More task implemented as a number game, we asked children to compare the arithmetic outcomes of pairs of stimuli, such as 2 groups of 4 dots versus 4 groups of 2 dots, or 2x4 versus 4x2.



We found that children's symbolic mastering predicts their performance on non-symbolic trials, independently of their age or the grade they are in. While symbolic masters can identify that 2 groups of 4 dots and 4 groups of 2 dots contain the same number of dots, children who do not yet master symbolic multiplication are purely relying on estimation to compare spatially organized dot arrays that can be interpreted as a multiplication, and struggle to recognize commutative situations in non-symbolic contexts.

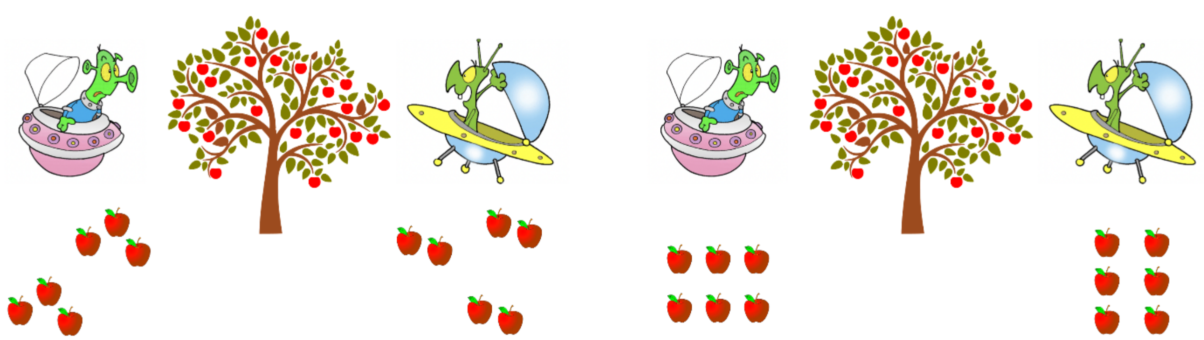
In a second session, children watched a 5-minute video explaining the commutative principle of multiplication and tested their knowledge via a short quiz including immediate feedback. They were then asked to play the number game again. The second session was conducted online in most cases, but some children watched the video, answered the questions, and played the number game while undergoing a brain imaging exam with MRI. As we are still in the process of collecting brain imaging data, we have not yet started its analysis. At the behavioral level, we found a small but significant learning effect on symbolic trials, but no significant improvement on non-symbolic trials. These results altogether seem to indicate that understanding the commutative principle of multiplication emerges as an offshoot of formal symbolic knowledge.

Study of the precursors of commutativity in preschoolers

Marie Amalric (Postdoctoral Researcher); Nick Kendall (Undergraduate Research Assistant); Elizabeth Spelke (Principal Investigator)

One way children learn large numbers is by understanding that they are composed of smaller numbers. And realizing that each number is unique even if it can be composed in different ways is essential to develop comprehensive numerical skills. For example, adults know that both buying 2 bags of 4 apples and 4 bags of 2 apples will result in buying 8 apples. But per the previous study's findings, most school-age children do not spontaneously perceive this result before mastering multiplication. They, however, spontaneously understand that buying 4 apples and 2 apples is the same thing as buying 2 apples and 4 apples. Does that mean that, contrary to addition, children do not possess precursory knowledge of the commutative principle of multiplication?

In the present study, we addressed this question by asking 5-year-old children to judge whether two characters got a fair or an unfair share of apples in various situations probing commutative multiplication and addition, and mere identity. To investigate the preferential underlying representations, the groups of apples were displayed with and without geometric cues of symmetry, as well as with and without verbal descriptions.



We found that additive commutativity is generally more accurately perceived than multiplicative commutativity, and that verbal descriptions were not helpful. Perhaps more importantly, we found that even before children learn formal arithmetic in schools, they do possess early intuitions of commutative multiplication if the symmetry intrinsically contained in commutativity is clearly apparent. Our results may provide useful insights on how to best introduce commutativity at school.

Can preschoolers track exact five objects?

Yiqiao Wang (Graduate Student), Susan Carey (Co-Principal Investigator), Elizabeth Spelke (Co-Principal Investigator)

This project aims to study the development of children's integer concepts. As adults, we know some key properties of integers. For instance, we have an exact representation of each integer that we can distinguish each one from the others. Previous research has shown that there are two preverbal systems that can support our exact representations of small numbers (i.e., numbers up to three or four). However, it's still an open question where the capacity to represent large, exact numbers comes from. We hope to find an answer through a case study investigating young children's representation of the number five. We chose the number five because it's where the two preverbal systems reach their limitations. In our current study, we ask when in development children have a non-linguistic representation of exact five and whether this is related to their number word knowledge.

We recruited children who age from 36 to 54 months and who speak English as their primary language. Each child played two games with an experimenter in a Zoom session. The first game was to measure whether children can track and represent exact numbers of objects. In this game, children saw certain numbers of stars hide into an empty box. On half of the trials, they saw all the stars come out of the box, and on the other half of the trials, they saw all but one stars come out. At the end of each trial, children were asked whether all the stars have come out. The second game was to measure children's number word knowledge. Children were asked to put certain numbers of objects on a plate upon hearing the number words. This game sorted children into two groups: Children who have understood the cardinal principle that the last number words used when counting objects refers to the cardinal value of the set and those who haven't. Children who understand the cardinal principle are believed to know the cardinal meanings of all the number words in their count range including five and they therefore have at least one way to represent a set of exact five – relying on the counting procedure to generate a set of five objects. Children who have not understood the cardinal principle, on the other hand, are believed to know only a subset of the number words in their count range and do not know how counting relates to numbers. We are interested in finding out if there is a difference in children's performance in the first game between children who understand cardinal principle and those who do not.

Data collection for this project is ongoing, and we hope to share the findings in the next newsletter!

What Comes Next?

Jenna Hughes (Undergraduate Research Assistant); Briony Waite (Lab Manager); Anthony Yacovone (Graduate Student); Jesse Snedeker (Principal Investigator)

Have you ever felt like you knew what someone was going to say before they said it? This phenomenon is known as *linguistic prediction*, and in this study, we are interested in learning more about how adults and children make these predictions during comprehension. Research has indicated that adults, compared to children, find it easier to predict what someone is going to say before they say it. Thus, we wanted to investigate the differences between adults' and children's predictive abilities. We think that children may not make as reliable predictions as adults, meaning they may have more variability in the types of guesses they give.

This study was conducted online using Zoom with monolingual English-speaking children aged 5-6 years old. During a Zoom call with a researcher, your child listened to a children's story while watching a cartoon. Occasionally, the cartoon would pause, and your child would be prompted to guess the next word in the story. In psycholinguistic research, this method is called a *cloze* *task*, and it is used to assess the predictability of certain words given the preceding sentence context. If you were listening to the story with your child, you might have noticed that some of the words seemed much easier to guess, and others were really hard!

For example, here's a sentence from the story that your child heard during the study:

1. *The library was a huge room with thousands of books stacked on rows of shelves that went all the way up to the _______ .*

If we asked adults to listen to this sentence and guess the next word, we would expect most of them to say *ceiling.* However, children might give a wider range of answers like *sky, roof,* or even *moon*. We don't know exactly why this is, but we think children may pay less attention to the context of the whole story, and instead use the current sentence to make predictions.

So far, the results from this study indicate that adults tended to give more accurate predictions than children, and children gave more responses that were irrelevant to the story context. This study is important as it provides us with concrete evidence for predictive abilities in children. Future directions will involve using the data about how predictable certain words are in future studies, as well as further studies investigating children's sensitivity to the correctness of their predictions.

Thanks for playing with us!

Picture Detective

Margaret Kandel (Graduate Student); Jesse Snedeker (Principal Investigator)

In this study, we were interested in investigating whether webcam eye-tracking methods are sensitive enough to detect information about real-time language processing in kids. We often use our in-lab eye-tracker to test how listeners process the words and sentences they hear, and we wanted to know whether webcam eye-tracking methods could be used in a similar way. In this study, we collected eye-movement data using an automatic gaze estimation algorithm called WebGazer (https://webgazer.cs.brown.edu) as well as via webcam video recording over Zoom. The Zoom video recordings were hand coded frame-by-frame to indicate gaze direction.

We tested how well these two methods distinguished looks to different parts of the screen as well as whether they could be used to replicate a well-established language processing effect called the phonemic cohort effect. Prior in-lab experiments have shown that as a listener begins to hear the name of a picture on the screen (e.g. "bed"), if there is another picture on the screen whose name starts with the same sounds (e.g. "belt"), the listener will initially look to both pictures as they hear the start of the word (e.g. "be-"). Listeners will continue to look at both images until the sounds they hear no longer match both names (e.g. when they hear the "d" in "bed"). This effect shows that listeners are continuously trying to match the sounds they are hearing with the words they know instead of waiting until they've heard a complete word before trying to identify which word it was.

This study was run with 5–6 year-olds who were native speakers of American English. Participants completed this study while in a Zoom meeting with the experimenter. In each trial of the experiment, children were presented with a set of pictures and heard an instruction telling them to look at one of them (the target image). In one version of the experiment, there were two pictures on the screen in each trial: one on the left side of the screen, and one on the right. In another version, there were four pictures in each trial: one in each quadrant of the screen (top left, top right, bottom left, bottom right). When WebGazer detected a look to an image, the area around it lit up, allowing the participants to select the target image with their eyes.

We manipulated whether or not there was an image on the screen whose name started with the same sounds as the target image name (a competitor image). In order to assess the eye-tracking methods' ability to discriminate looks to the different image locations, we analyzed how well they detected looks to the target image when there was no competitor image. We also analyzed whether the methods detected more looks to competitor images (e.g. belt) when they appeared with a target starting with the same sounds (e.g. bed) compared to a different target (e.g. car), as we would expect given the phonemic cohort effect.

We found that both webcam eye-tracking methods were able to distinguish looks to the different screen locations we tested; both methods detected increased looks to the target images after participants heard instructions telling them to look at them. However, WebGazer detected looks with lower accuracy, and target looks appeared delayed compared to the hand-coded Zoom video data and what we typically expect from in-lab studies. The cohort effect was visible in the Zoom video data for both the two image version of the experiment and the four image version. WebGazer only detected a cohort effect in the two image version, and this effect was smaller and delayed compared to the Zoom data.

These results suggest that it is possible to do eye-tracking studies with children virtually, though researchers should carefully consider what eye-tracking method they use given the type of eye movements they would like to detect. WebGazer data processing is much faster than hand-coding webcam video, though it is best applied to study effects that do not require high spatial or temporal sensitivity to detect. For effects that require more spatiotemporal accuracy, hand-coding videos appears to be well worth the extra effort. We are currently working on a follow-up study (The Super Vision Game) to further investigate WebGazer's performance so that we can make study design recommendations for researchers planning to use it.

The Super Vision Game

Margaret Kandel (Graduate Student), Jesse Snedeker (Principal Investigator)

Eye-tracking is a very useful method for language research, as we can use it to gain insight into how listeners interpret words and sentences in real-time. In this study, we are assessing how well a webcam eye-tracking software called WebGazer (https://webgazer.cs.brown.edu) works to track children's eye-movements. We started experimenting with running studies virtually (including eye-tracking studies) while our lab was closed during the COVID-19 pandemic. We found that online experiments can be more convenient for parents and children than in-lab studies, as children can complete the studies from the comfort of their own home, and we can reach families who live further away from our lab. The WebGazer software has the potential to make eye-tracking studies even more convenient for parents and kids, as it can be run in a web browser without an experimenter present, meaning that participants would be able to complete studies whenever is most convenient for them. We first piloted the task in virtual experiment sessions with families over Zoom. We are now testing how well WebGazer works in an unsupervised experiment that children complete on their own time from their own homes.

This study is being conducted with English-speaking children aged 4–12 years old. All participants need to complete the study is a computer with a webcam as well as either the Google Chrome or Mozilla Firefox web browser. During the experiment, children see colorful plus signs (like this: +) that appear in different parts of the screen. Their job is to look at the plus signs that appear and to stare at them until they disappear! The experiment is quick and easy; it typically takes 10–15 minutes to complete.

Data collection for this study is still ongoing. We plan to analyze how far the center of the plus signs are from where WebGazer estimates participants to be looking, whether WebGazer accuracy increases with age, and what locations on the screen are easier for the software to distinguish. Our goal is to be able to provide other researchers with recommendations on how best to use this tool when running studies with children.

What Information Do Kids Use to Identify Words?

Margaret Kandel (Graduate Student); Nan Li (Postdoctoral Researcher); Jesse Snedeker (Principal Investigator)

When you are listening to someone speak, there are multiple potential sources of information that could be used to help you identify the words that you are hearing. One obvious source of information is the sounds contained in the word. Another potential source of information is the sentence context in which the word appears. In this study, we are interested in whether children are able to use contextual information in addition to sound information as they identify the words they hear in a sentence.

We are conducting this study with American English-speaking children aged 4–7 years old. In this study, participants are seated in front of an eye-tracker. In each trial of the experiment, they see four pictures and hear a sentence that includes the name of one of the pictures. Their job is to select the picture whose name they hear in the sentence. In each sentence, there is a critical word that appears before the participant hears the name of the picture they will select. We manipulate how predictable the critical word is and whether there is another picture on the screen whose name starts with the same sound (a cohort competitor). For example, participants may hear the critical word "bed" when there is a picture of a belt on the screen. We will test whether participants look more at the cohort competitor image (e.g. belt) than at an unrelated picture (e.g. stream) as they begin to hear the critical word (e.g. bed); this will let us know whether they consider the cohort competitor image as a potential match to the sounds they were hearing. If participants are able to use sentence context to constrain word identification, we expect fewer looks to the cohort competitor image when the critical word is predictable than when it is not.

Data collection for this study is just starting, so stay tuned for results!

Understanding Social Interactions and Social Relationships

Narges Afshordi (Postdoctoral Researcher); Susan Carey (Principal Investigator)

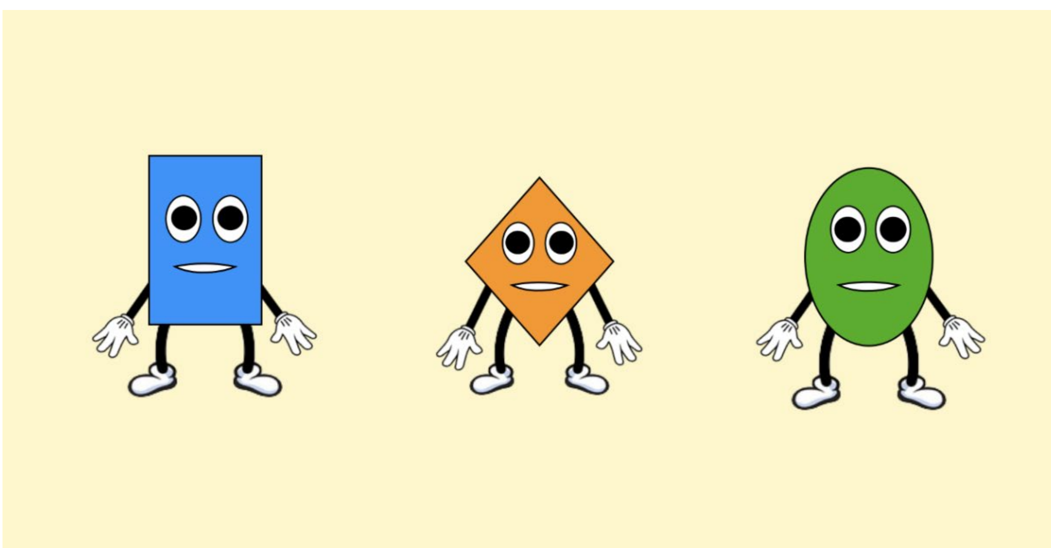
Imitation is everywhere. By copying those around us, we learn, we bond, and we fit in. We also notice when other people imitate each other. Can young children do this too? In this study, we show preschool-aged children several pairs of characters and in each pair, one person copies the actions of the other. For instance, the woman in the yellow shirt in the figure below moves her leg like the woman in the green shirt. After children watch a few of these animations, we ask them which one in a pair was copying someone else.

Our current findings suggest that children as young as three years can succeed at this task if they are given a chance to remember the characters and their actions, but not otherwise. We are continuing this study with four-year-olds to see whether the ability to recognize the copier is better at this age than at age three. Thank you for your participation, and stay tuned for final results!

Leaders or bullies?

Narges Afshordi (Postdoctoral Researcher); Susan Carey (Principal Investigator)

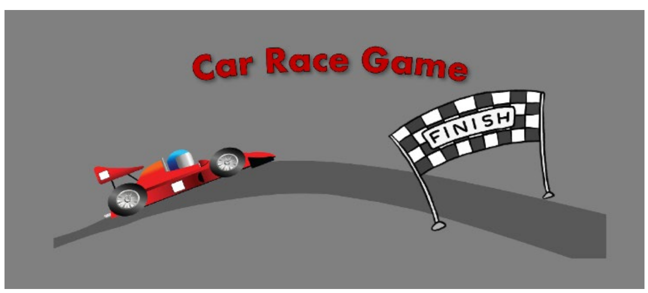
Many human interactions are marked by a difference in status. Sometimes the higher status person in the relationship is benevolent and helpful (i.e. a leader). Other times, they are forceful and self-motivated (i.e. a bully). In this study, we wanted to know whether children aged 4-12 years can distinguish a leader from a bully, and whether they would prefer to learn from one over the other. We showed children simple animations of 3 characters (see below), a bully, a leader, and Dimo, a central character who was lower in status than both. We then asked them a number of questions, such as who Dimo likes best, is more afraid of, and would rather sit next to. We also asked children who they would choose to solve interpersonal conflicts (e.g. when each person wants a different outcome to happen). Finally, we showed children pictures of unfamiliar objects and asked them who they would prefer to learn the name of those objects from. Our final results are not yet ready, but we found that children from the youngest ages distinguished the leader from the bully, and with age preferred to have the leader solve conflicts. However, they were willing to learn names for unfamiliar objects from both the leader and the bully. So far, it appears that children think that status affects interpersonal situations, but is not relevant to learning information.



Prediction in children with and without autism

Tanya Levari (Postdoctoral Researcher); Briony Waite (Lab Manager); Jesse Snedeker (Principal Investigator)

In this study, your child played a whole bunch of different games, both in-person and on Zoom. For some of the games, they were set up for an electroencephalogram (EEG) recording, and we recorded their brain responses while they watched, listened, and completed tasks. These games might not have seemed connected, but we think they will help us understand different aspects of prediction and to see if predictive ability differs between children with and without autism. For example, in one game, your child saw a racecar move across a screen, and their job was to press a button when they thought it reached a finish line. The car disappeared from the screen before reaching the finish line, so they had to predict when it would arrive. This is called a time-to-arrival task, and it helps us understand ***motion prediction***. Previous studies have found that people will click the button too early when the car is invisible for a longer stretch of time, and too late when it is invisible for less time. In another game, your child was asked to first listen and then tap along to sequences of sounds that included occasional omissions. This helps us understand ***temporal prediction***. Previous work has found that there is a distinct neural response when someone is expecting to hear a sound and does not hear it, allowing us to see if children know when to expect a sound based on the pattern.



Your child also listened to a story while we recorded their brain activity. We are looking at the brain's response to each word in the story to see whether children's brain waves, like those of adults, are sensitive to various word features, such as frequency and predictability. This helps us understand ***linguistic prediction.*** Studies using EEG with adults have discovered that there is a specific brain wave that happens when a person hears a word, called the n400 wave. The size of this brain wave changes depending on how easy a word is to understand and incorporate into a sentence. For example, when a word is very frequent, like "dog", the

n400 wave is smaller than when a word is less frequent, like “axolotl”. In addition, the wave is smaller when a word is very predictable, and larger to words that are surprising! For example, imagine hearing the following; “On a windy day Johnny liked to go fly his…” You wouldn’t be very surprised if the next word was “kite”, but you would be very surprised if you heard “blimp”. The size of the n400 brainwave would show exactly that – the n400 wave would be smaller if you heard “kite” and larger if you heard “blimp”.

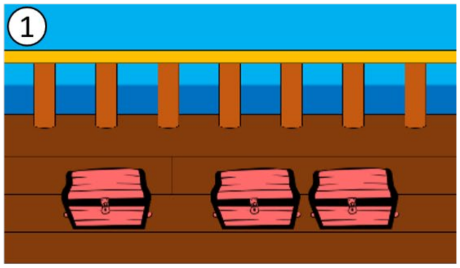
We are still in the process of collecting data for this study, and we aren’t sure what we’ll find yet. Stay tuned for more results next year!

We loved seeing families in person for this study. Thank you so much for participating!

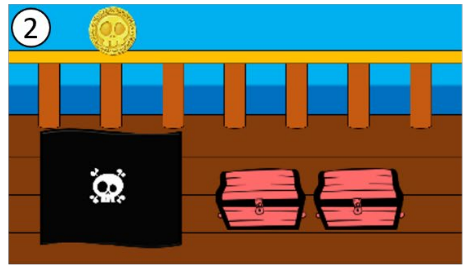
Which chest do you want to pick?

Michael Huemer (Postdoctoral Researcher); Peter Mazalik (Research Assistant); Brian Leahy (Graduate Student); Susan Carey (Principal Investigator)

Previous studies from our lab suggest that young children cannot think about alternative possibilities before they turn 4. For example, when children are presented with the task shown in Figure 1. A coin is hidden in a single occluded chest and another coin is hidden in an occluded pair.If given a chance to choose one chest and receive its contents, choosing the singleton chest is the safe bet, because each member of the pair might be empty. Yet 3-year-olds choose a member of the pair almost half the time. Why don’t they choose the singleton chest? This is expected if 3-year-olds do not think about the coin in the pair might be in either chest. Rather, they make an assumption about which chest of the pair the coin is in. Then they make a 50/50 choice between the two chests (the single chest and one member of the pair) that they "know" has a coin in it.

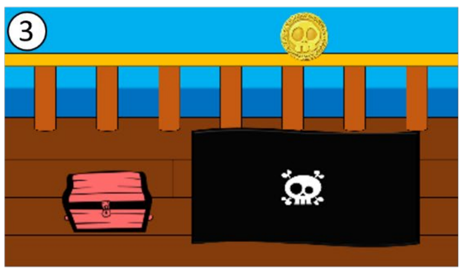


"Here, we have three new chests."
"Watch closely, here come the coins..."



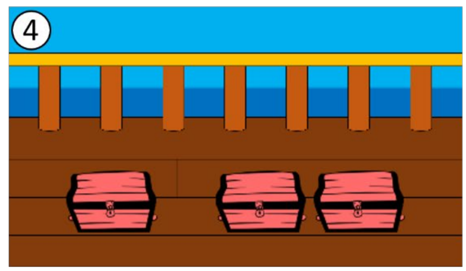
"Here comes the first coin..."

Coin falls into a chest behind the flag.



"... And here comes the second coin..."

Coin falls into a chest behind the flag.



"Which chest are you really, really sure has a coin inside it?"

Figure 1. The 3-chest task for studying the ability to reason about multiple possibilities.

The response behavior of 3-year-olds in the online version of this task (shown in Figure 1) is the same as in studies conducted in the lab before the pandemic. In the current pilot study, we wanted to see if this was also true for older 2-year-olds so that we could use the online version of this task for future studies. However, we found that the older 2-year-olds were not as attentive in our online task as they are in the lab, and will invite children of this age back to the lab for further studies.

Which cup do you want to pick?

Michael Huemer (Postdoctoral Researcher); Isobelle Hawkins (Undergraduate Research Assistant); Brian Leahy (Graduate Student); Susan Carey (Principal Investigator)

Previous studies from our lab suggest that young children cannot think about alternative possibilities before they turn 4. For example, when children are presented with the task shown in Figure 1 (3-cup task). A coin is hidden in a single occluded cup and another coin is hidden in an occluded pair. If given a chance to choose one cup and receive its contents, choosing the singleton cup is the safe bet, because each member of the pair might be empty.

In a previous study we tried to help children by having 6 cups instead of only a pair of cups on the side where one cannot be sure to find a coin (Figure 1, 7-cup task). We thought that children will now find it easier to realize that in the singleton cup there must be a coin while each of the other cups merely possibly contains a coin when there are more cups that might be empty. We found that 3-year-olds did not chose the singleton cup more often in the 7-cup task than in the 3-cup task. In our ongoing study we try to help children even more. Now we show them in an online version of this task that the coin is moving back and forth in a random way while the coin is behind the occlude, and we tell them, “The computer is moving the coin in funny ways, and we cannot tell where it goes”. This is thought to help children understand that they do not know which of the cups the coin is in. We plan to complete the data collection for this study in the next couple of weeks.

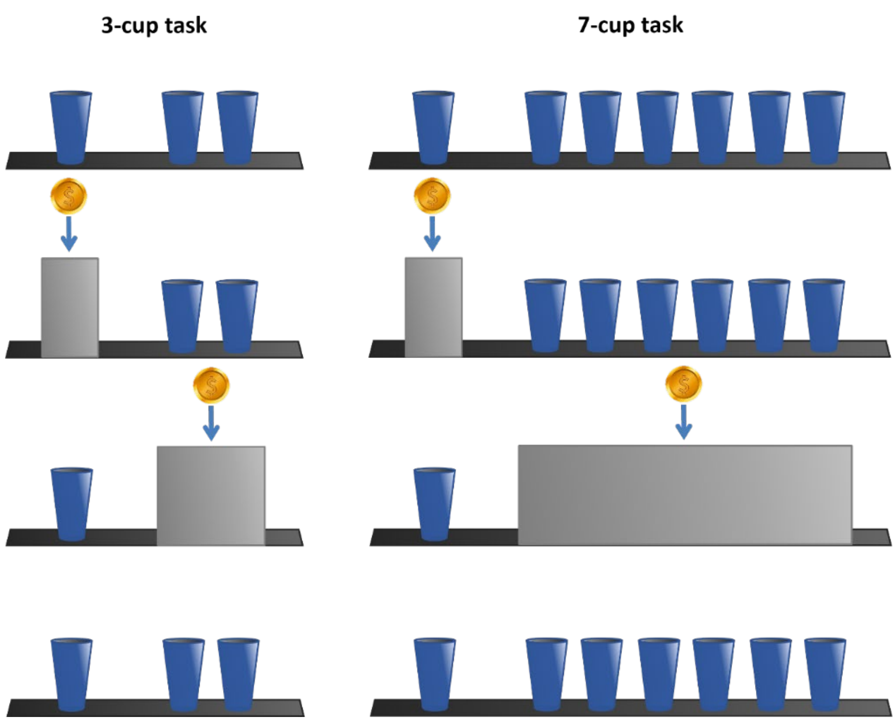


Figure 1. The 3-cup and 7-cup tasks for studying the ability to reason about multiple possibilities.

The response behavior of 3-year-olds in the online version of this task (shown in Figure 1) is the same as in studies conducted in the lab before the pandemic. In the current pilot study, we wanted to see if this was also true for older 2-year-olds so that we could use the online version of this task for future studies. However, we found that the older 2-year-olds were not as attentive in our online task as they are in the lab, and will invite children of this age back to the lab for further studies.

Children’s developing understanding of possibility and perspective taking

Michael Huemer (Postdoctoral Researcher); Isobelle Hawkins (Undergraduate Research Assistant); Brian Leahy (Graduate Student); Britta Schünemann (Postdoctoral Researcher); Susan Carey (Principal Investigator)

Previous studies from our lab suggest that young children cannot think about alternative possibilities before they turn 4. For example, when children are presented with the apparatus shown in Figure 1. We could drop one marble into the straight channel on the left and another marble into the branching channel on the right at the same time. Children could place a small wagon underneath one of the three exits to try to catch a marble. Since the marble on the left follows a determinate path, while the marble on the right might go either of two ways, the safe bet is to put the wagon under the left exit.

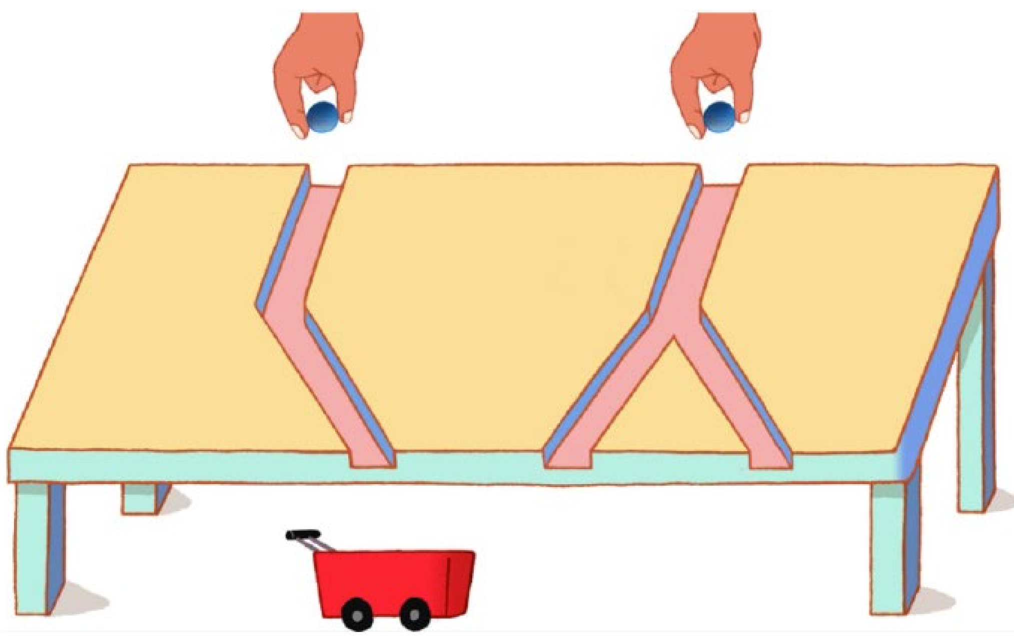


Figure 1. The 3-exit task for studying the ability to reason about multiple possibilities.

At the same age at which children experience difficulty with possibility tasks, children also manage perspective taking tasks poorly. Perspective taking is the ability to understand feelings and thoughts of others. An example of a task which is widely used to study perspective taking is called the “false belief task”, depicted in Figure 2. In this task, children see Lisa putting her teddy in the red box, and then leaving the scene. In Lisa’s absence, her brother moves the teddy from the red box to the yellow box. Then Lisa returns, and the children are asked where Lisa will look for the teddy. Most children below the age of 4 struggle with this task and predict wrongly that Lisa will look for the teddy in the yellow box.

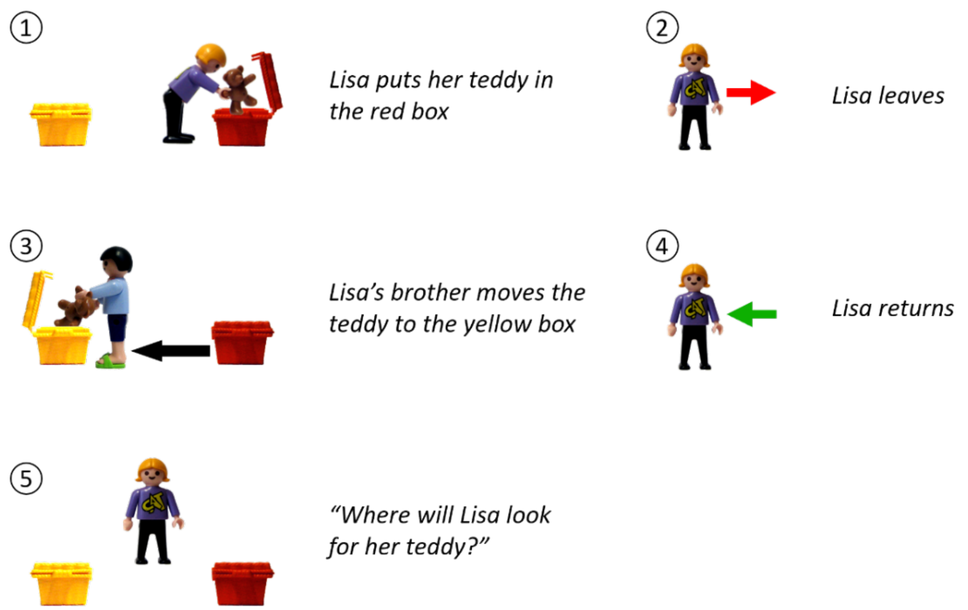


Figure 2. The “false belief task” for studying the ability to engage in perspective taking.

We proposed that there is a relation between children’s developing ability to solve possibility and perspective taking tasks. To investigate this, we presented 3 to 4-year-olds with the 3-exit task, and the false belief task. We found that there was no relation between these two tasks. It seems that the possibility task is more difficult than the false belief task for children in the tested age range. Understanding possibility may be acquired later in children’s development than the ability of perspective taking.

Might and might not: Modal concepts and modal comprehension

Brian Leahy (Graduate Student); Eimantas Zalnieriunas, Scarlett Close, Jessica Hitchcock (Research Assistant); Susan Carey (Principal Investigator)

Several studies from our lab suggest that many children cannot think about alternative possibilities before they turn 4. However, children start talking about possibilities around their second birthday. What explains this disconnect? To explore this, we developed an apparatus that allows us to systematically test children's comprehension of possibility verbs (in our study, *can*, *hafta (have to)*, and *will*), and to test the relationship between the ability to talk about possibilities and to solve problems that require thinking about possibilities.

Children saw the apparatus shown in Figure 1. We could drop two marbles into this apparatus at the same time. Children could place a small wagon underneath one of the openings to try to catch a marble. Since the marble on the left follows a determinate path, while the marble on the right might go either of two ways, the safe bet is the marble on the left.

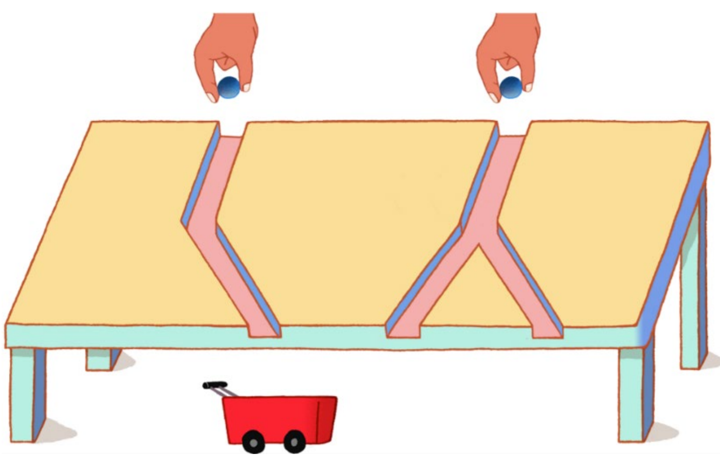


Figure 1: A nonlinguistic test of the ability to think about multiple possibilities.

Then we tested children's comprehension of the language of possibilities (Figure 2). We would hold a marble above one of the slides, indicate one of the outlets, and ask, "If I drop a marble in here, can it/will it/does it hafta come out here?" We repeated this question 6 times for each verb (2 entrances x 3 outlets each). This gave us a strong test of children's comprehension of modal verbs.

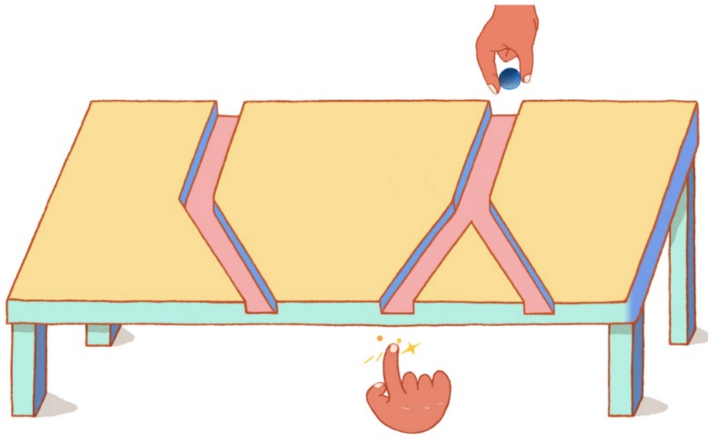


Figure 2: A test of children's comprehension of possibility verbs.

After asking all of these questions, we gave kids six more chances to catch a marble. This allowed us to check whether children were able to learn to solve the problem, either by learning over trials or through being prompted to think about the possibilities by our questions.

In the first study we tested children from ages 4 through 7 and adults. We found that even 4-year-olds tended to answer 'can'-questions correctly; however, they gave the same pattern of responses to 'hafta' and 'will' questions, suggesting that they have not differentiated these three verbs. While they use these words from age 2, it is possible that they do not understand their meanings even at age 4.

In the first followup, we tried to make sure kids were thinking about all the things they needed to think about before we asked them the questions. When their attention had been drawn to all the relevant facts, we found that about half of 4-year-olds and almost all 5-year-olds could tell the difference between what can happen and what has to happen. The rest of the kids still treated the verb "have to" as though it means "can"!

Now we are working on extending this study to 3-year-olds. So far about a quarter of 3-year-olds correctly answer questions about what can happen. But almost none correctly answer questions about what has to happen. At this age, most children just answer "yes" to every question, no matter what question we ask.

Where's the bunny? A study of children's representations of alternative possibilities

Brian Leahy (Graduate Student); Stephanie Alderete (Research Assistant), Susan Carey (Principal Investigator)

Several recent studies in our lab have turned up a funny result. Suppose you see a stage with four cups, organized into two pairs. The left pair is covered up, and a prize is hidden in one of those two cups–but you can't tell which; then the right pair is covered up, and a prize is hidden there too. Then all the cups are uncovered, and the experimenter shows you that the leftmost cup has nothing in it. You get one chance to choose one cup and get what's inside. The smart bet is to choose the remaining cup form the pair on the left, because it surely holds a prize, while the two members of the pair are both 50-50 risks.

When we show this situation to 3-year-olds, they choose the singleton 60% of the time: more than expected by chance (⅓), but much less than perfect. There is an easy way to get a lot more prizes. Why are they so bad?

A recent study from another lab showed that when color is used to help group the cups into sets (e.g., the left pair is both green cups, while the right pair is both orange cups) and the hiding is done by a sock puppet, 3-year-olds perform much better, making the smart choice 75% of the time. But it's not exactly clear why they're better at it. We want to test this to find out why, but first we have to replicate their findings. So far we haven't been able to: we implemented their procedure online, but the results turned out exactly as we always see: 3-year-olds make the smart choice about 60% of the time.

We'll keep working on the design; perhaps it will work better if we run it in person, in the lab instead of online. Once we can get their results replicated, it'll be time to start figuring out why their version is easier than ours!

Do young infants recognize social intimacy?

Ashley Thomas (Postdoctoral Researcher); Elizabeth Spelke (Principal Investigator)

In all human societies, people form ‘thick’ relationships, which are characterized by strong and enduring attachments and specific moral obligations. While thick relationships often occur between genetic relatives, not all thick relationships are between genetic relatives and not all genetic relatives form thick relationships. How do young children identify thick relationships in their social environments? One possible cue is the sharing of bodily fluids, which occurs within thick relationships across many cultural settings. In these studies, we found that children, toddlers, and infants infer that individuals who act in ways which suggest saliva-sharing have a different kind of relationship with one another than do other social partners. Children expected saliva sharing to happen within nuclear families, and infants and toddlers expect these behaviors to occur between individuals who respond to one another in states of distress. We’re currently running a study to ask whether even 4 month old infants use the same cues.

Can Infants Distinguish Kinds Through Object Labels?

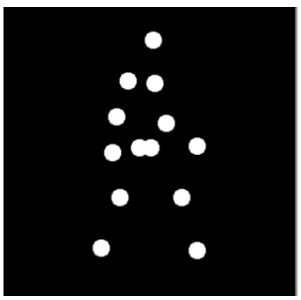
Cristina Sarmiento (Lab Manager); Joon Yang (Research Fellow); Alexandra Brind (Research Assistant); Elizabeth Spelke (Principal Investigator)

Past research has shown that infants as young as 10 months old expect distinct nouns to refer to different kinds. This study aimed to see if 12-month-old infants could do the same on Zoom. Babies were presented with videos of an actor finding objects behind an occluder and labeling them the same or different. The objects were either identical or different so sometimes the expectations were correct and other times they were incorrect. There were not clear patterns in pilot data, and therefore we have stopped data collection.

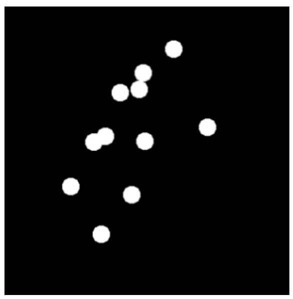
Point Light Display of Biological Motions

Cristina Sarmiento (Lab Manager); Elizabeth Spelke (Principal Investigator)

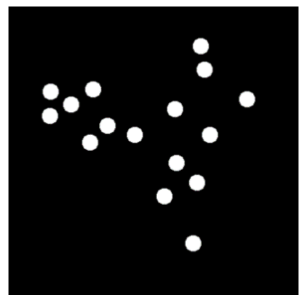
Past research has shown that humans have a preference for biological motion. In this study we're interested in whether infants are sensitive to the natural motion of trees. Our videos show babies an arrangement of dots that are shaped to look like a human or tree that appear upright or in a random arrangement. We are curious to see whether 6 to 12-month-old infants spend more time looking at the arrangement of dots that are shaped like a human and tree when they appear upright. So far, we have found that infants show a slight non-significant preference for the human upright arrangement. Our next step is to include another form of biological motion (an animal) to see if infants prefer an animate object (the human) over an inanimate object (the tree).



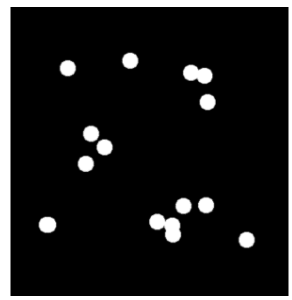
Human Upright



Human Random



Tree Upright



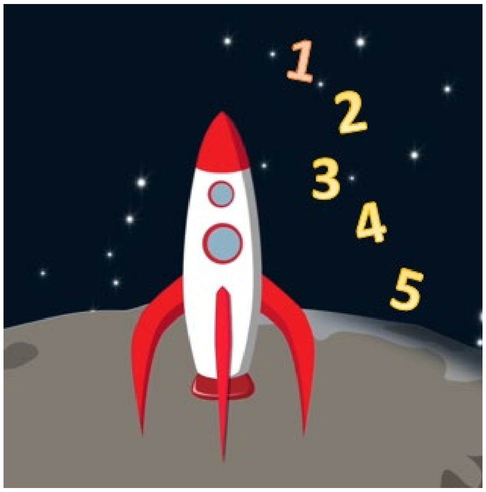
Tree Random

Numbers across Languages

Akshita Srinivasan, Simge Topaloglu (Graduate Students); Jesse Snedeker, Elizabeth Spelke (Principal Investigators)

Learning numbers and math operations like arithmetic are important milestones in school for young kids. But can the language that a child is acquiring make it harder (or conversely, easier) for them to learn numbers?

In most cultures, numbers are organized around a base-10 system, which uses 10 and its powers to represent numbers. This structural logic is also reflected in the number terms that languages use, but not all languages encode their numbers in the same way. For example, a language like Mandarin has very 'regular' number words that transparently reflect the base-10 structure; since 11 is called 'ten-one' and 20 is called 'two-ten.' Compared to the simplicity of Mandarin, English has more opaque number words, since 'eleven' does not reveal that this number is made up of 'ten' and 'one', and 'twenty' also does not reveal that this number is related to 'two' and 'ten'.



In this study, we test kids acquiring a diverse set of languages (such as English, Mandarin, Turkish, Hindi, Tamil) that all differ in their numbers' relative degree of transparency; and we seek to find out what the implications of number word transparency/ opaqueness might be for young kids' developing math abilities.

We play number-related games with kids to see how high they can count, whether they understand what operations change the number of a set and what operations conserve it, or whether they understand the base-10 logic.

We are still in the process of collecting data for this project so stay tuned for our findings! This research would not be possible without the help of the children who took part in the study and their parents. Thank you so much for your participation, and we are hoping to see you in our lab for our future studies!

Early reasoning about relationships from affiliative cues

Vanessa Kudrnova (Postgraduate Researcher); Ashley J. Thomas (Postdoctoral Researcher); Elizabeth Spelke (Principal Investigator)

Earlier work suggests that infants make predictions about future behaviors between two social partners based on imitation. For instance, when four-month-olds watch one character imitate and one not imitate a common target, they only expect the imitator (as opposed to non-imitator) to approach and affiliate with its target. Notably, when 12-month-old infants watch one central character imitate one puppet and not another, they reach more for the not-imitated puppet.

Moreover, infants and toddlers appear to think about different types of relationships when watching responses to distress. For example, when a puppet expresses distress 8-10- and 16–18-month-olds expect (look first and longer at) a person who previously shared food (commonly occurring between close others), rather than a person who passed a ball with a puppet (commonly occurring between more distanced others), to react.

However, from this literature it is unclear whether infants and toddlers see imitation and responses to distress as cues of the same underlying type of relationship, and whether infants and toddlers think differently about behaviors depending on whether they are reasoning about the targets or non-targets of imitation compared to those who perform imitation. Hence, across a series of experiments, the current study asks whether 11.5 to 12.5 and 16.5 to 18.5-month-olds see imitation as predictive of who will respond to another individual's distress, and whether these predictions are affected by the direction of imitation. For this, babies watched a set of videos of one puppet imitating a central human character and one not, and another set in which one puppet was imitated by a central human character and one not. After each set of videos, the relevant central character expressed distress and we measured which puppet babies looked at first and for how long, as though they expected that puppet to respond.

Our findings so far show that infants and toddlers expect the imitator and imitated puppet to respond to their central character in distress. Therefore, we incorporated a control exploring whether these expectations were based on the relationship (i.e., imitation interaction) babies saw, or prosocial traits of the imitator and imitated. Interestingly, when the central characters were replaced by new individuals not involved in the prior imitation interactions, we found that babies were at chance with looks towards puppets, suggesting that infants and toddlers only expect the imitator and imitated to react to the distress of their social partner, and not just anyone.

We are now running a study exploring whether infants make predictions from imitation specifically in the case of a response to distress. Therefore, babies now watch imitation interactions after which the puppets' social partners express distress, or alternatively laugh. We look forward to seeing the results.

A big thank you to all the families taking time to take part in our research!

Intention-Based Evaluations of Helping in Toddlers and Children

Brandon Woo (Graduate student); Sanghee Song (Research Assistant); Elizabeth Spelke (Principal Investigator)

Do toddlers prefer characters who cause positive outcomes over characters who cause negative ones, even if the outcomes that characters cause are unintended? In several studies of infants and toddlers, we have asked whether early social evaluations privilege intentions versus outcomes. We have found that 15-month-old toddlers are not outcome-based in their social evaluations; instead, they preferentially look to and reach for characters with helpful intentions, even if characters unintentionally cause negative outcomes. We have also presented older children with the same puppet shows, and found that they form similar evaluations. This paper is now under review (see https://psyarxiv.com/eczgp). We have also shared in conference proceedings (https://escholarship.org/uc/item/8k02x1mx) related findings in 8-month-old infants from previous years.

Goal Understanding and Infants' and Toddlers' Evaluations of Helping

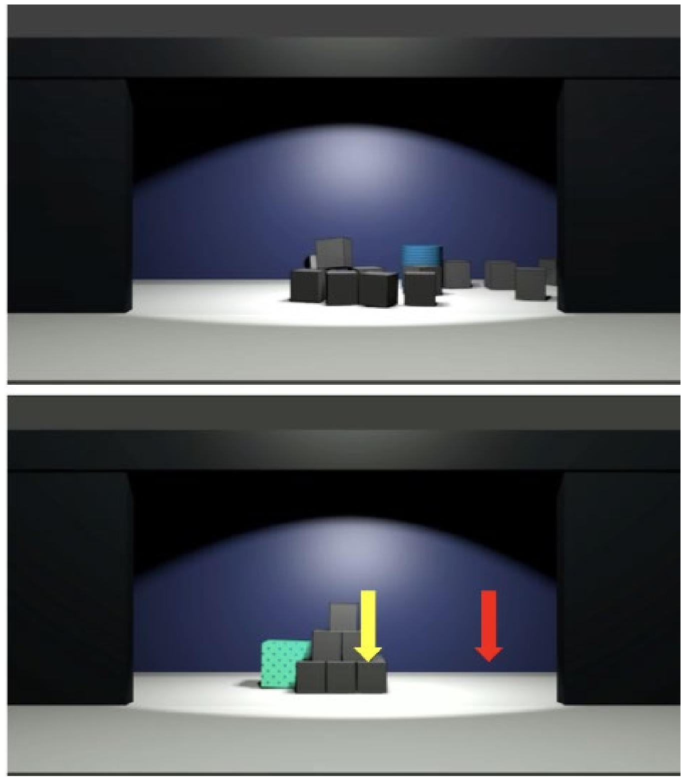
Brandon Woo (Graduate Student); Mia Taylor (Research Assistant); Elizabeth Spelke (Principal Investigator)

A large and growing body of work has found that infants prefer characters who help a protagonist over characters who hinder the protagonist in the pursuit of their goals. Importantly, if infants and toddlers are seeing these actions as helping and hindering the protagonist, then they must understand the protagonist's goal. In the present studies, we presented 8-month-old infants and 15-month-old toddlers with a protagonist who grasped a toy that was inside a box. We found that infants both: (i) inferred that the protagonist desired the toy, rather than just the box; and (ii) preferred a character who later provided access to that toy, even when it was no longer in the same box. This paper is now under review (see working paper: https://psyarxiv.com/mtprn).

Heavy and Light: Children's Reasoning About Mass

Brandon Woo (Graduate Student); Delaney Caldwell, Judy Zheng (Research Assistants); Vanessa Kudrnova (Research Intern); Tomer Ullman (Assistant Professor); Elizabeth Spelke (Principal Investigator)

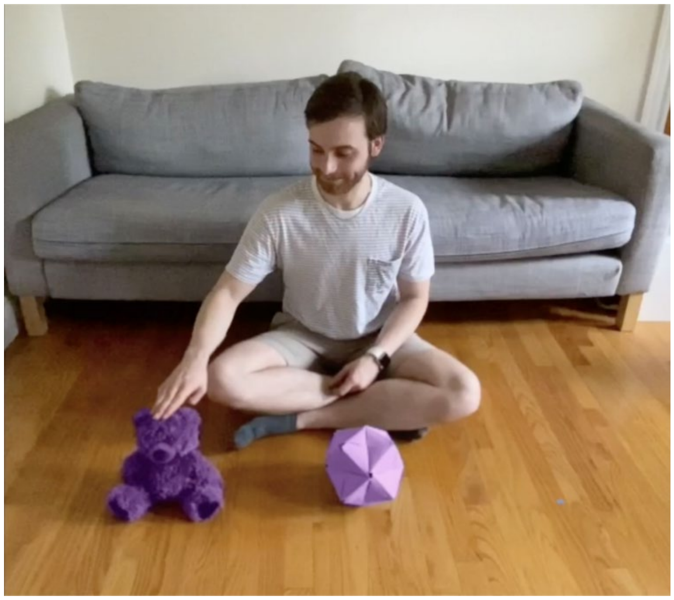
A blue block hits a block tower, and knocks all the blocks down. A green block, moving at the same speed, hits the same block tower, and only knocks a few blocks over. Which block is heavier? How will each block act in a new situation (e.g., after being pushed)? This study asks whether 4- to 5-year-old children can (i) reason about the mass of objects based on how they act in different situations and (ii) make predictions about how objects will act in new situations. Some past work has argued that children should find it difficult to form such predictions. We have been trying to use new stimuli for this study with children, and so, we are unable to comment on trends in data.



Goal Understanding in 3-Month-Old Infants

Brandon Woo (Graduate Student); Shari Liu (Postdoctoral Researcher, MIT); Elizabeth Spelke (Principal Investigator)

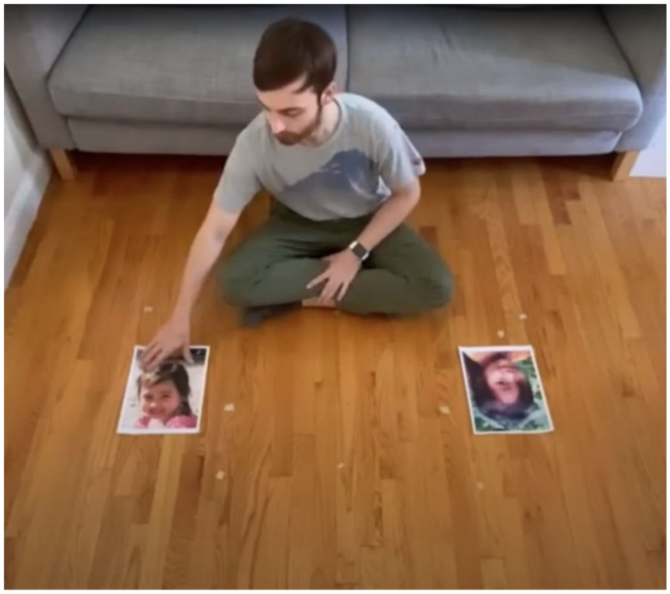
A person sits in front of two objects, a ball on the left and a bear on the right. The person repeatedly reaches for one of the objects (e.g., the ball), always in the same location. Later, the two objects switch positions. Which object will the person reach for now: the same object, or for a different object in the original location that he had reached for? Previous work has found that whereas 6-month-old infants expect the person to continue reaching for the same object, 3-month-old infants do not. The present studies ask: What do 3-month-old infants understand about others' goals? Why have they failed, in past research, to appreciate the goals of others' reaches? We explored one possibility: that 3-month-old infants may not yet appreciate that an object's identity matters more than its location. In a series of experiments, we provide evidence that 3-month-old infants can learn that someone's reaching is guided by a goal to act on a particular object or on a particular location, depending on the evidence that infants observe. These findings suggest that infants rationally learn about others' actions. We have now submitted this paper for publication (see working paper: https://psyarxiv.com/dx2er/).



Representing Others' Experiences in Toddlers and Children

Brandon Woo (Graduate Student); Mia Taylor, Adrian Tsang, Sanghee Song (Research Assistants); Elizabeth Spelke (Principal Investigator)

The ability to appreciate others' experiences is important for communication, learning, and cooperation. Do toddlers appreciate that other people can look at the same object, and experience it differently depending on their perspectives (e.g., as upright versus upside-down)? In several experiments, we have now found that toddlers struggle to appreciate that pictures that are upright and upside-down to themselves may be in other orientations to other people. Instead, toddlers appear egocentric. Yet, in one experiment, we have found that toddlers appreciate differences in what pictures are visible to them and to others. We have since replicated these findings over several experiments, and found that older children succeed in tasks where younger toddlers fail. (For a recent working paper, see https://psyarxiv.com/3gbj6.) In ongoing work, we are exploring whether toddlers may be more sensitive to others' experiences when these experiences are conveyed by language.



Children's Social Inferences about Close Social Relationships: Do children use food sharing to infer close relationships?

Cameron Calderwood (Research Assistant); Ashley Thomas (Professor); Elizabeth Spelke (Principal Investigator)

Previous research has found that children expect saliva-sharing to occur more often in familial relationships than between friends. However, there is still limited experimental evidence exploring children's ideas about close social relationships. For example, whether children think about saliva sharing as a cue of social closeness or as simply something that demarcates family from friends. Thus, the current study aims to understand children's ideas about close relationships and sharing saliva. We are testing whether children expect those who share saliva to be more likely to share a secret; more upset if the relationship ends; more likely to respond to the partner being sad and whether they think those who share saliva are 'closer'.

This study is for children ages 6-8 years. We will tell them stories about children sharing food that either requires saliva sharing (licking a lollipop), no saliva sharing (sharing cookies) or toys. Then we will ask them questions about people's relationships.

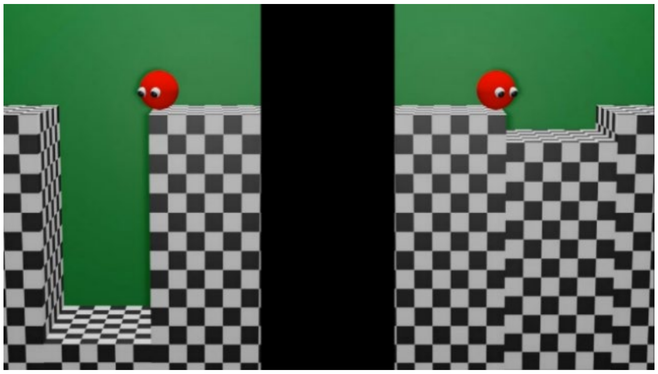
We are currently collecting data but hypothesis that children will expect those who share saliva to be more likely to share secrets, more upset when their social partner is moving, more likely to comfort the partner and will be socially closer on the 'inclusion of the other in the self' scale.

Infant's expectations of other people's behaviors in dangerous situations

Manasa Ganesh Kumar (Undergraduate Research Assistant); Shari Liu (Postdoctoral Researcher); Elizabeth Spelke (Principal Investigator)

Previous research conducted in the lab indicates that by the age of 13 months, infants expect other people to avoid dangerous actions when a safer alternative is available to get to a reward. These experiments have also indicated that, by the age of 13 months, infants expect other people to value rewards for which they engage in dangerous actions. Following up on these results, we decided to conduct another short experiment to investigate whether infants expect other people to behave differently in riskier and safer situations.

In this activity, infants watch videos of a cartoon character approaching deeper and shallower trenches simultaneously. This cartoon character stops at the edge, peers into the trench, and starts pulsing. While pulsing, the cartoon character either makes a laughing or crying sound. When the sounds are played in the background, we begin to examine infants' looking preferences. If 13-month-old infants, in this activity, prefer to look at the cartoon character peering into the deeper trench when the crying sound is played, it will indicate that they expect this specific character to cry. Hence, such a looking preference means that infants expect people in riskier situations (and not people in relatively safer conditions) to elicit crying noises.



This study is still in the beginning stages, so we do not yet have results to share. If the study yields a significant result, in the future, we would also be interested in investigating whether infants expect other people to experience specific emotions such as fear or distress in dangerous environments. This work would not be possible without you, and we would like to thank you for your participation! We hope that you will continue participating with us in the future.

Games to enhance children’s reading and numerical skills

Akshita Srinivasan (Graduate Student) and Elizabeth Spelke (Principal Investigator)

Learning how to read and learning about numbers are two important aspects of early schooling. However, they can be hard for children to learn. While learning how to read, children need to figure out what letters and their combinations sound like. In English, this is especially hard as the same letters can take on different sounds. For example, the letter “u” sounds different in “nut” and “put”. Similarly, learning about numbers can be hard, as the symbols and words that represent them do not transparently convey their meanings. For example, a number word like “eleven” doesn’t convey to children that it is made up of ten and one. The meaning of written symbols like “23” depends upon understanding place value codes, where the value of a digit varies based upon the position it occupies in a number, making “23” and “32” different quantities. Given the importance and difficulty of learning reading and about numbers, we designed two board games for 6-7-year-old-children. The reading game, called Bingo, focuses on the compositionality of the English alphabet and the number game, called Find and Move, focuses on the compositionality of numbers. We hope that these fun games will help children become better prepared for learning in school.

In this study, children and their caregiver(s) will participate in two Zoom sessions, 2-3 weeks apart, from their own homes. In between the Zoom sessions, children will play either the reading game or the number game at home with their caregiver or sibling. During both the Zoom sessions, we will ask children some questions about numbers and words. We are interested in finding out whether these games improve children’s school-relevant reading and numerical skills.

Data collection for this project is ongoing, so stay tuned for the findings!

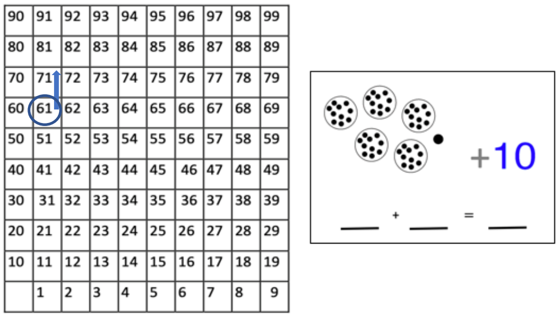


Figure 1: Number game. In this game, children first locate the number of black dots (51) on the board (left) and then add the number in blue (10). They are taught to jump up the line to add 10, that is move from 51 to 61 to find the final answer.

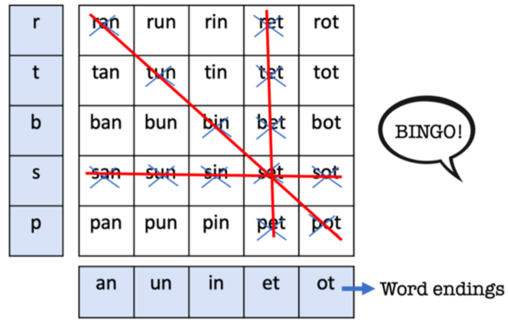


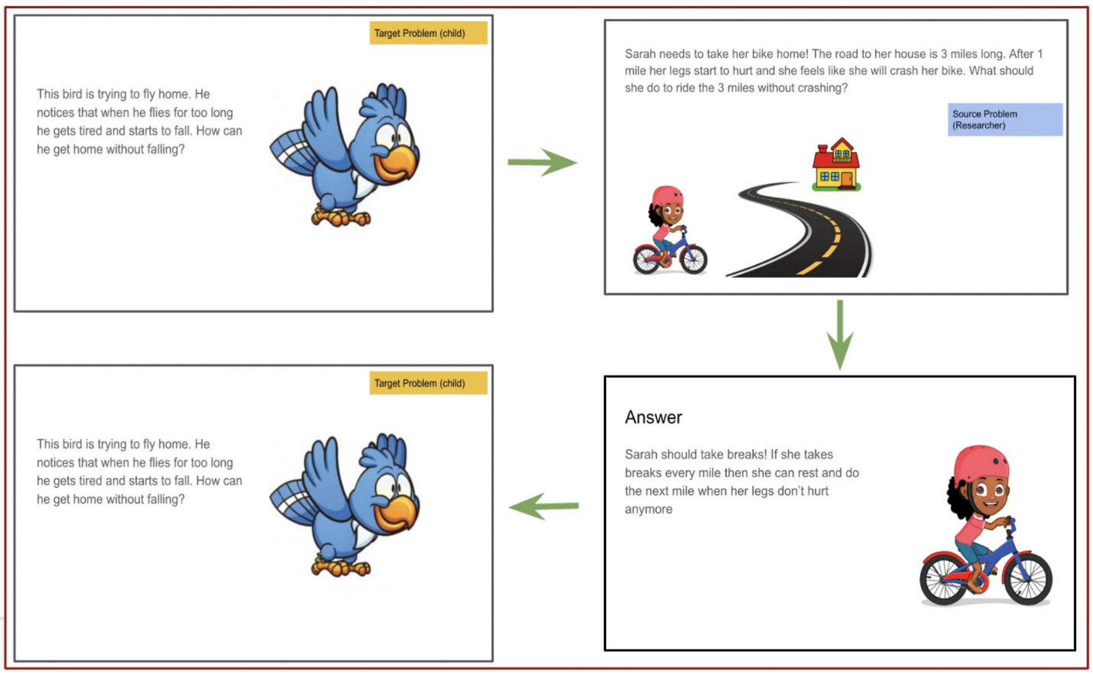
Figure 2. Reading game. In this game, children try to find words, like "pun", on the board by using the word beginnings like "p" on the left and word endings like "un" at the bottom. Once they find 5 consecutive words in a row, column, or along the diagonal, they say "bingo" and move to the next level.

Positive Transfer and Analogical Problem Recognition in Four-Year-Olds: Mathematical Perspectives

Nicholas Kendall (Undergraduate Research Assistant); Marie Amalric (Postdoctoral Researcher); Elizabeth Spelke (Principal Investigator)

Children are known to use analogies in their daily lives as a way to make sense of the world. They have been shown to recognize and apply analogies in certain settings if there is enough surface similarity between two problems. As children begin formal education, an analogy is a tool used in an attempt to aid them in the development of mathematical skills. Math problems are often accompanied by a story component throughout schooling. We are studying the ability of young children to recognize analogies and utilize them in order to solve a new problem (positive transfer). Testing occurred over Zoom with 4-year-olds. Each child played a 15-minute game with three distinct question sets with two problems per set. Each question set is composed of a target problem and a source problem. The first question set presents a duration over time problem (Shown above). The second question set requires the children to combine shapes and then count the number of sides. The third question set involves approximating numbers with the commutative principle.

The participant has the chance to solve these target problems before and after they see an analogous source problem and its solution. One problem is concrete (uses numbers/geometry) and the other one is more abstract (story with no numerical component). We also test the effect the order of presentation has when showing either the complex/abstract or simple/concrete math problem as the source problem. Missing the first attempt and correctly answering the second attempt is counted as a successful "Positive Transfer". The child was then presented with a matching task to test analogical recognition.

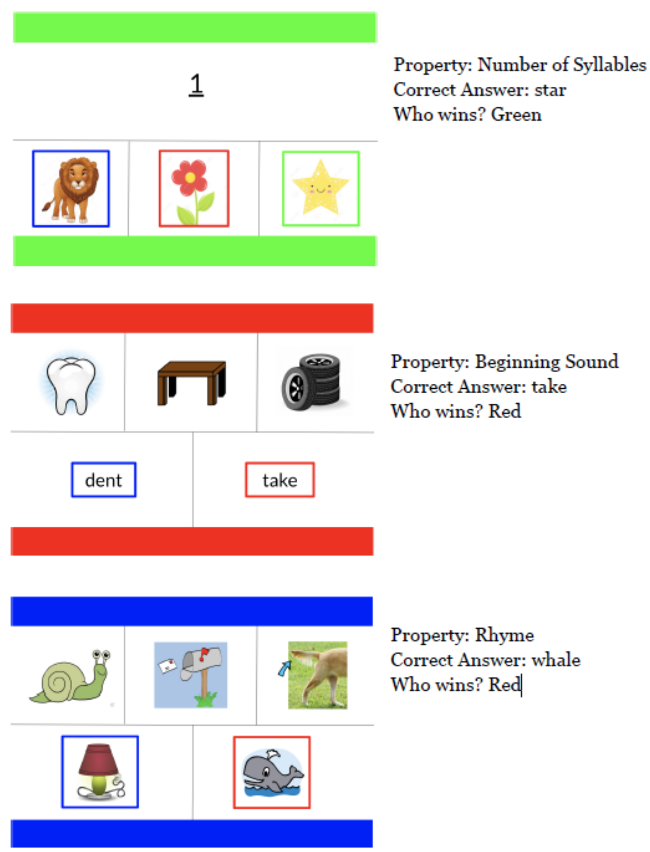


So far we are finding that some 4-year-olds have the ability to recognize analogies and use analogies. Most interestingly, those abilities were independent of each other. We have conflicting results regarding the effect the level of concreteness has, where it had no effect in some question sets then the opposite effect for matching and positive transfer in two question sets.

Find Sound: A game-based intervention to improve children's reading skills

Gianna Zades (Undergraduate Researcher), Akshita Srinivasan (Graduate Student), Lucia Vilches (Undergraduate Research Assistant), Elizabeth Spelke (Principal Investigator)

Reading is an essential skill that helps children grow intellectually and better understand the world around them as they learn to decipher both sound and meaning from written language from a young age. Reading broadens a child's horizons, as readers of both fiction and factual texts discover and explore physical, cultural, and social worlds beyond their immediate experience. Learning to read is a process that formally starts in kindergarten and continues until early elementary school. Previous research has shown that early reading skill is a predictor of children's success in the rest of their education. In order to help support children's reading skills at home, we have developed a fun game that focuses on teaching the different sound properties of words including rhyme, alliteration, and syllables.



Our study tests the effectiveness of this reading game by comparing it to a similar game in the domain of geometry. We hope that these games will help improve kindergarten age (5-6.5 years) children's school-relevant reading and geometry skills in the short term. We are testing this by sending a game to each child's home. The geometry game, "Find Shape," and the reading game, "Find Sound," are played as a game of war, where children are asked to find which shape or word belongs in a group based on its geometric or sound properties. The study involves two remote zoom sessions that are about 45-60 minutes long and at-home gameplay for about 2-3 weeks in between the two sessions. In the first session, we ask children questions on the computer about reading and geometry and then another researcher teaches the child and parent how to play the game. Then, parents are asked to play the game with their child on 8 separate occasions. Finally, in the second zoom session the child and parent play one more round of the game and then a researcher asks the child more questions related to geometry and reading.

While we've only just begun testing these games in late May 2022, we've gotten feedback from parents and families expressing children's engagement and enjoyment of the game. Stay tuned for the findings!

Find Sound is played with two players. Each player has their own deck. For each card, the child must find the answer on the bottom (blue, red, or green) that matches the symbol or word represented by an image on top. Once the players have determined the correct answer, the player whose card has borders that are the same color of the correct answer gets to keep both player's cards in their 'winning pile.' After repeating for each card in a deck, the player with the most cards in their winning pile wins.

Predicting words in stories

Tanya Levari (Postdoctoral Researcher); Briony Waite (Lab Manager); Jesse Snedeker (Principal Investigator)

In this study, your child listened to a story while we recorded their brain activity. We are looking at the brain's response to each word in the story to see which features (e.g. frequency and predictability) help us understand what we are hearing. Studies using EEG with adults have discovered that there is a specific brain wave that happens when a person hears a word, called the n400 wave. The size of this brain wave changes depending on how easy a word is to understand and incorporate into a sentence. For example, when a word is very frequent, like "dog", the n400 wave is smaller than when a word is less frequent, like "axolotl". In addition, the wave is smaller when a word is very predictable, and larger to words that are surprising! For example, imagine hearing the following; "On a windy day Johnny liked to go fly his…" You wouldn't be very surprised if the next word was "kite", but you would be very surprised if you heard "blimp". The size of the n400 brainwave would show exactly that – the n400 wave would be smaller if you heard "kite" and larger if you heard "blimp". In our study we are interested in seeing when the ability to predict upcoming words develops and how it changes as children age. In addition, your children completed a vocabulary task. This task will allow us to see if the ability to predict words develops with children's age or their language ability.